LABORATORY MANUAL

KINEMATICS AND DYNAMICS LAB

II B.TECH -II Semester

Prepared by
R. Chandra Sekhar Reddy
Asst.Prof

2017-18

DEPARTMENT OF MECHANICAL ENGINEERING

CMR ENGINEERING COLEGE
(Approved by AICTE, New Delhi & Affiliated JNTU, Hyderabad)
Kandlakoya (V), Medchal Road, RR.Dist – 501401

VISION OF THE INSTITUTE

- To be recognized as a premier institution in offering value based and futuristic quality technical education to meet the technological needs of the society

MISSION OF THE INSTITUTE

1. To impart value based quality technical education through innovative teaching and learning methods
2. To continuously produce employable technical graduates with advanced technical skills to meet the current and future technological needs of the society
3. To prepare the graduates for higher learning with emphasis on academic and industrial research.

VISION OF THE DEPARTMENT

To be a center of excellence in offering value based and futuristic quality technical education in the field of mechanical engineering.

MISSION OF THE DEPARTMENT

M1. To impart quality technical education imbibed with values by providing state of the art laboratories and effective teaching and learning process.

M2. To produce industry ready mechanical engineering graduates with advanced technical and lifelong learning skills.

M3. To prepare graduates for higher learning and research in mechanical engineering and its allied areas.

PROGRAM EDUCATIONAL OBJECTIVES (PEOS):

PEO 1: The Graduates will exhibit strong knowledge in mathematics, sciences and engineering for successful employment or higher education in mechanical engineering.

PEO 2: The Graduates will design and implement complex modeling systems, conduct research and work with multi disciplinary teams.

PEO 3: The Graduates will be capable of communicating effectively with lifelong learning attitude and function as responsible members of global society.

PROGRAM OUTCOMES (POS):

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

. PROGRAM SPECIFIC OUTCOMES(PSOS):

PSO.1 Design a Thermal system for efficiency improvement as per industrial needs.

PSO.2 Design and manufacture mechanical components using advanced manufacturing technology as per the industrial needs.

COURSE NAME: KINEMATICS AND DYNAMICS LAB

CO No.	**Course Outcomes (CO's)**
CO1	Understand types of motion
CO2	Analyze forces and torques of components in linkages
CO3	Understand static and dynamic balance
CO4	Understand forward and inverse kinematics of open loop mechanisms

COURSE OUTCOMES (COs) – PROGRAM OUTCOMES (POs) MATRIX:

CO's/PO's	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	-	3	-	-	-	-	-	-	-	-
CO2	3	3	-	3	-	-	-	-	-	-	-	-
CO3	3	3	-	3	-	-	-	-	-	-	-	-
CO4	3	3	-	3	-	-	-	-	-	-	-	-

COURSE OUTCOMES (CO) – PROGRAM SPECIFIC OUTCOMES (PSO) MATRIX:

CO's/PSO's	PSO1	PSO2
CO1	-	3
CO2	-	3
CO3	-	3
CO4	-	3

GENERAL INSTRUCTIONS FOR LABORATORY CLASSES

1. All the students must follow the prescribed dress code (apron, formals, shoes) wear their ID cards
2. All the students should sign in login register.
3. All students must carry their observation books and records without fail.
4. Students must take the permission of the laboratory staff before handling the machines in order to avoid any injury.
5. The students must have basic understanding about the theory and procedure of the experiment to be conducted.
6. Power supply to the test table/test rig should be given in the presence of only through the lab technician.
7. Do not LEAN on and do not come CLOSE to the equipment.
8. Instruments like TOOLS, APPARATUS and GUAGE sets should be returned before leaving the lab.
9. Every student is required to handle the equipment with care and follow proper precautions
10. Students should ensure that their work areas are clean.
11. At the end of each experiment, the student must take initials from the staff on the data / observations taken after completing the necessary calculations.
12. The record should be properly written with following section in each experiment:
    a) Aim of the experiment
    b) Apparatus / Tools / Instruments required
    c) Procedure / Theory
    d) Model Calculations
    e) Schematic Diagram
    f) Specifications / Designs Details
    g) Tabulations.
    h) Graph
    i) Result and discussions.
13. Students should attend regularly to all lab classes.
14. Day- to- day evaluation of student performance is carried out and recorded for finalizing internal marks.

SCHEME OF EVALUATION FOR EXTERNAL LABS

Correctness of Write up and Precautions	Conduct Experiment & observations	Model Calculations	Results and Graphs	Viva
Marks: 10	**Marks: 20**	**Marks: 15**	**Marks: 15**	**Marks: 15**
Total Marks: 75 Marks				

SCHEME OF EVALUATION FOR INTERNAL LABS

Day to Day Evaluation ------15 Marks					Internal Exam------10 Marks				
Uniform	Observation &Record	Performance of experiment	Results	Viva Voce	Correctness of Write up and Precautions	Conduct Experiment & observations	Model Calculations	Results and Graphs	Viva Voce
Marks:2	**Marks:3**	**Marks:3**	**Marks:4**	**Marks:3**	**Marks:2**	**Marks:2**	**Marks:2**	**Marks:2**	**Marks:2**
Total Marks: 15+10=25 Marks									

LIST OF EQUIPMENT

1. Simple pendulum
2. Compound pendulum
3. Torsional vibration apparatus
4. Motorized gyroscope
5. Universal governor apparatus
6. Whirling of shaft apparatus
7. Cam analysis apparatus
8. Free and forced vibration
9. Static and dynamics balancing
10. Journal bearing

LIST OF CONTENTS

EXPERIMENT 1

SIMPLE PENDULUM

AIM:

To verify the relation

$$T = 2\pi \sqrt{L/g}$$

Where T- Periodic Time in sec

L- Length of Pendulum, cms

THEORY:

A pendulum is a body suspended by a fixed point so it can swing back and forth under the influence of gravity. Pendulums are frequently used in clocks because the interval of time for each complete oscillation, called the **period**, is constant. The period of this pendulum can be made longer by increasing its length, as measured from the point of suspension to the middle of the suspended body, or bob. This simple pendulum consists of a bob suspended at the end of a cord. Its period is based on length, not amplitude.

DESCRIPTION OF SETUP:

For conducting the experiment, a beach ball is supported by nylon thread into the chuck. It is possible to change the length of pendulum by drawing the thread through chuck. This makes it possible to study the effect of variation of length on periodic time. A small ball may be submitted for large ball to illustrate that the period of oscillations is independent of the mass of the ball.

PROCEDURE:

1. Attach the beach ball to one end of thread.

2. Loosen the nut at the top of chuck and draw the thread to adjust the length.

3. Allow the ball to oscillate and determine the periodic time T by knowing the time for say 10 oscillations.

4. Repeat the experiment by changing the length.

5. Complete the observations table as given below.

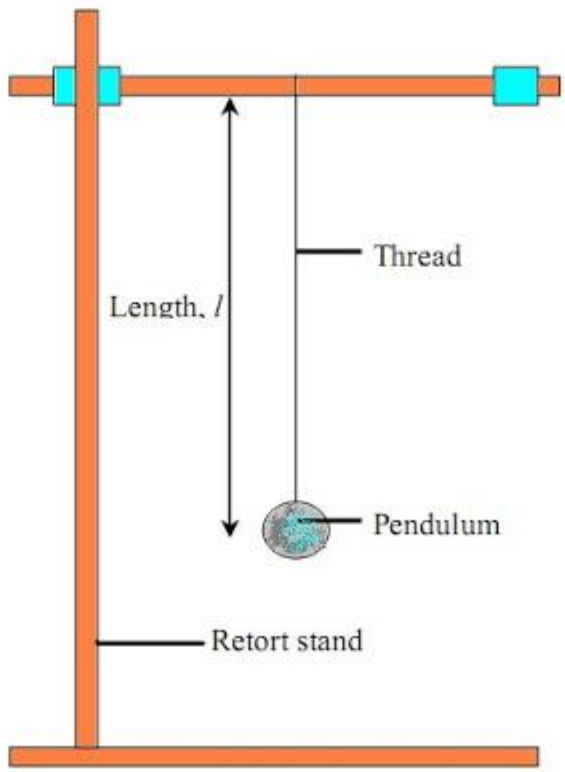
OBSERVATION TABLE:

S. no	L (cms)	No. of oscillations n	Time for n oscillations in sec (T)	T(Experimental) t/n	T(Theo)

CALCULATIONS:

$T = 2\pi \sqrt{L/g}$

Frequency = 1/T



RESULT:

EXPERIMENT 2

COMPOUND PENDULUM

AIM:

1. To determine the radius of gyration ‘k’ of given pendulum

2. To verify the relation $K_{expt} = \sqrt{\frac{T^2 \times g(OG)}{\sqrt{4\pi}} - OG^2}$

Where, T- periodic time

K- Radius of Gyration about C.G

OG- Distance of the C.G of rod from support

l- Length of suspended pendulum

DESCRIPTION:

The compound pendulum consists of steel bar. The bar is supported by the knife edge. It is possible to change the length of suspended pendulum by supporting the bar in different hole.

PROCEDURE:

1. Support the rod in any one of the hole.
2. Note the length of suspended pendulum and determine OG.
3. Allow the bar to oscillate and determine T by knowing the time for say 10 oscillations.
4. Repeat the experiment with different length of suspension.
5. Complete the observation table given below.

OBSERVATION TABLE:

S.NO	L Cm	OG Cm	No. of osc. N	Time in ‘t’ sec	T_{expt} 1/n	K_{expt}	K_{theo}

CALCULATION:

Find ‘k’ experimental from the relation

$$K_{expt} = \sqrt{\frac{T^2 \times g(OG)}{\sqrt{4\pi}} - OG^2}$$

Find K_{Theo} $K_{theo} = L / (2\sqrt{3})$

Compare value of k obtained theo. & expt.

RESULT:

EXPERIMENT 3(A)

TORSIONAL VIBRATION OF SINGLE ROTOR SYSTEM (UNDAMPED)

AIM:

To determine the natural frequency of torsional vibration of single rotor system and compare it with the theoretical value.

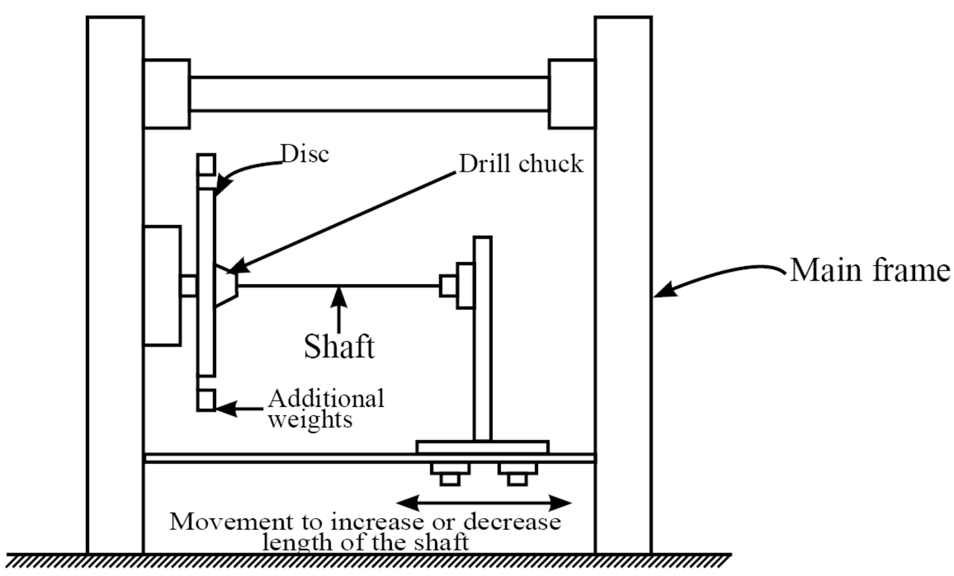
APPARATUS:

Shaft, Chuck key, Spanner, Measuring tape & Stopwatch.

DESCRIPTION:

In this experiment, one end of the shaft is gripped in the chuck. A heavy flywheel or disc free to rotate in ball bearing is fixed at the other end of shaft. The bracket with fixed end of the shaft can be moved to any convenient position along lower beam. The bearing housing is fixed to side member of main frame.

EXPERIMENTAL SETUP



PROCEDURE:

1. Fix the bracket at a convenient position along the lower arm
2. Grip one end of the shaft at the bracket by chuck
3. Fix the rotor on the other end of shaft.
4. Twist the rotor through same angle and release.
5. Note down the time required for 5 or 10 or 20 oscillations
6. Repeat the procedure for different lengths of shaft

FORMULAE:

1. Periodic time or Experimental period of vibration: T_{exp} / T_{act}

$$T_{act} = \frac{t}{n} \qquad (sec)$$

Where, t is time taken for ‘n’ oscillations

2. Theoretical period of vibration: T_{theo}

$$T_{theo} = 2p\sqrt{\frac{I}{K_t}}\,(sec)$$

Where I = Moment of Inertia of disc (Nms^2)

K_t =Torsional stiffness (Nm)

3. Torsional stiffness: K_t

$$K_t = \frac{GJ}{L} \qquad N\text{-}m/rad$$

Where G = modulus of rigidity (N/m^2)

L = length of shaft (m)

4. Polar moment of Inertia: J

$$J = \frac{pd^4}{32} \qquad (m^4)$$

$$\text{where} \quad d = \text{diameter of shaft} \,(m)$$

5. Moment of Inertia of Disc: I

$$I = \frac{WD^2}{8g} + \frac{2W_1R^2}{8g} \quad N\text{-} \; m/\sec^2$$

$$\text{where} \quad R = \text{Radius of rotation of weights on the arm} \,(m)$$

6. Experimental frequency of vibration

$$F_{exp} = \frac{1}{T_{exp}} \text{ or } \frac{1}{T_{act}} \quad (Hz)$$

7. Theoretical frequency of vibration

$$F_{theo} = \frac{1}{T_{theo}} \quad (Hz)$$

OBEERVITION:

1. Modulus of Rigidity : G = 80 GPa
2. Shaft Diameter : d = 4,5 or 6mm
3. Diameter of disc : D = 200mm = 0.2m
4. Mass of disc : M = 2.5 Kg
5. Weight of disc : W = 24.525 N
6. Weight of additional Mass : W_1 = 0.385 x 9.81 = 3.77685 N

TABULAR COLUMN:

Sl.No	Length of shaft ‘L’ (m)	No. of oscillations (n)	Time for n oscillations ‘t’ (sec)	Periodic time $T_{act} = t/n$
1				
2				

CALCULATIONS:

Sl.No	Number of oscillations ‘n’	Time taken for ‘n’ oscillations t (sec)	Period of oscillation / vibration (sec)		Frequency of vibration / oscillation (Hz)	
			T_{exp}	T_{theo}	F_{exp}	F_{theo}
1						
2						
3						

RESULT:

The frequency of torsional vibration of the single rotor system is determined and the experimental and theoretical values are tabulated and compared.

EXPERIMENT 3(B)

TORSIONAL VIBRATION OF TWO ROTOR SYSTEM

(UNDAMPED)

AIM:

To determine the natural frequency of torsional vibration of two rotor system and compare it with the theoretical value.

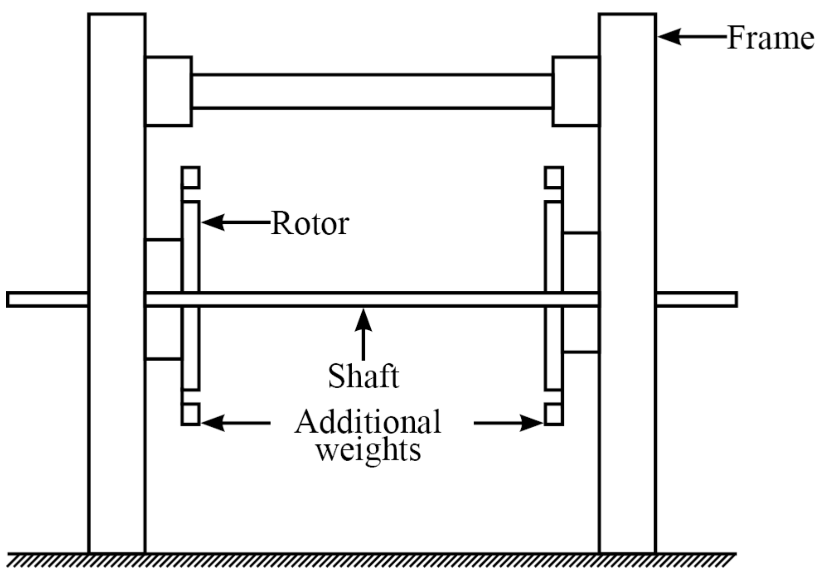
APPARATUS:

Shaft, Chuck key, Spanner, Measuring tape & Stopwatch.

DESCRIPTION:

Two discs, having different mass moment of inertia are clamped, one at each end of shaft by means of a collect. Mass moment of inertia of any disc can be changed by attaching a cross with weights. Both disc are free to oscillate in the ball bearing. This provides negligible damping during experiment.

EXPERIMENTAL_SETUP



PROCEDURE:

1. Fix disc A and disc B to the shaft and fit the shaft in the bearing
2. Deflect the discs A & B in opposite direction by hand release.
3. Note down the time required for ‘n’ oscillations 5, 10, 15, 20
4. Fit the cross arm to the disc A and attach equal masses to ends of cross arm.
5. Repeat the above procedure with different equal masses attached to ends of cross arm, and also by varying the length of this shaft.

FORMULAE:

1. Periodic time or experimental period of vibration:

$$T_{act} = \frac{t}{n} \quad (sec)$$

Where t=timefor‘n’oscillations

n = no. of oscillations

2. Torsional stiffness:

$$K_t = \frac{GJ}{L} \quad N\text{-} m/rad$$

Where G = Modules of Rigidity

J= Polar momentofinertia

$$J = \frac{pd^4}{32} \left(m^4\right)$$

3. Moment of inertia of Disc A:

$$I_A = \frac{W_A D_A^2}{8g} + \frac{2W_1R^2}{8g} \quad N\text{-} m/sec^2$$

W_A = Weight of discA (N)

D_A = Diameter of discA (m)

W_1 = Weight added (

4. Moment of inertia of Disc B:

$$I_B = \frac{W_B D_B^2}{8g} + \frac{2W_1 R^2}{8g} \qquad N - m/sec^2$$

W_1 =Weight attached to cross arm (N)

R = Radius of rotation of weight.

5. Theoretical period of vibration:

$$T_{theo} = 2\pi\sqrt{\frac{I_A \times I_B}{K_t (I_A + I_B)}} \qquad (sec)$$

6. Theoretical Frequency of vibration

$$F_{theo} = \frac{1}{T_{theo}} \qquad (Hz)$$

7. Experimental Frequency of vibration

$$F_{exp} = \frac{1}{T_{exp}} \qquad (Hz)$$

NOTE: If no weights are added to the cross bar, $W_1 = 0$

$$I_B = \frac{W_B . D_B^2}{8g}$$

OBSERVATION:

1. Modular of Rigidity for shaft Material: G = 80 GPa
2. Shaft Diameter : $d = 3 \times 10^{-3}$ m
3. Diameter of disc A : $(D_A) = 0.25$m
4. Diameter of disc B : $(D_B) = 0.20$m
5. Weight of disc A : $W_A = 3.85 \times 9.81 = 37.768$ N
6. Weight of disc B : $W_B = 2.5 \times 9.81 = 24.525$ N
7. Weight of additional mass added: $W_1 = 0.385 \times 9.81 = 3.77685$ N

TABULAR COLUMN:

Sl.No	No of oscillations 'n'	Time for n oscillations 't' (sec)	Weight attached (N)	Radius of Rotation (m)	Moment of Inertial of Disc A (Nm/s^2)	Moment of Inertial of DiscB (Nm/s^2)	Periodic time t_{act} = t (sec)
1							
2							
3							

Sl.No	Moment of inertial of Disc A (Nm/s^2)	Moment of inertial of Disc B (Nm/s^2)	Period of oscillation (sec)		Frequency of vibration (Hz)	
			T_{exp}	T_{theo}	F_{exp}	F_{theo}
1						
2						
3						

RESULT:

The frequency of torsional vibration of the two rotor system is determined and the experimental and theoretical values are compared.

EXPERIMENT 4

GYROSCOPE

AIM:

To determine the effect of gyroscope for different motions.

APPARATUS:

a. Gyroscope

b. Weight

c. Stopwatch.

DEFINITIONS:

Gyroscope

A gyroscope is a spinning body mounted universally to turn with an angular velocity of precession in a direction at right angles to the direction of the moment causing it but its center of gravity will be in a fixed position.

Precession

When a force is applied to the gyroscope about the horizontal axis, it may be found that the applied force meets with resistance and that the gyro, instead of turning about its horizontal axis, turns about its vertical axis and vice versa. It follows right hand thumb (screw) rule. Thus the change in direction of plane of rotation of the rotor is known as precession.

Gyroscopic Couple

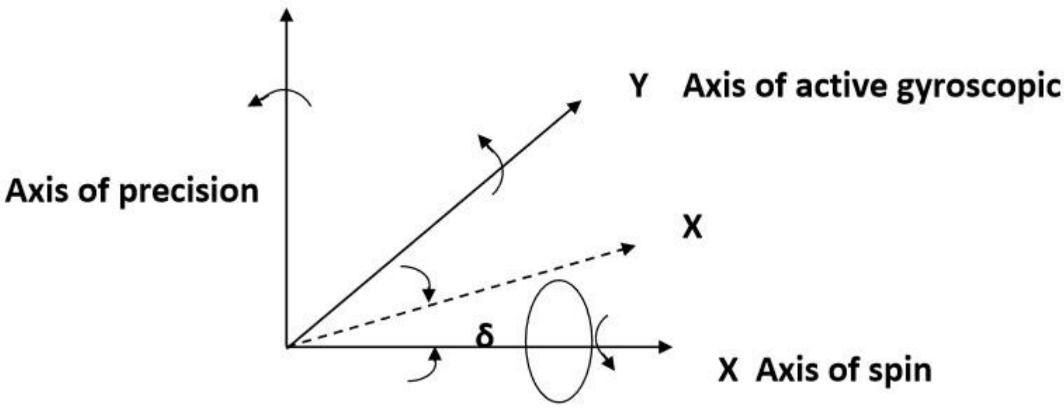
It is applied couple needed to change the angular momentum vector of rotating disc/Gyroscope when it processes. It acts in the plane of coupe which is perpendicular to both the other planes (plane of spin and plane of precession) it is given as:

$$T = I \times \omega \times \omega_p$$

Where, I = Moment of inertia of rotor.

ω = Angular velocity of rotor.

ω_p = Angular velocity of precession



THEORY:

The gyroscope has three degrees of freedom. The first axis is OX called spin axis on which the body is spinning (revolving). The second axis is OY called Torque & OZ axis is called precession axis on which the body moves opposing the original motion. It may be observed that these entire three axis are mutually perpendicular such a combined effect is known as precession (or) Gyroscopic effect.

The analysis of the gyroscopic principles is based on Newton's laws of motion and inertia. When the torque is spinned, the gyroscope exhibits the following two important characteristics.

1. Gyroscopic inertia
2. Precession

Gyroscopic Inertia:

It requires a high degree of rigidity and its axle keeps pointing in the same direction no matter how much the base is turned about. It depends upon angular velocity (ω) weight (w) at which the weight is concentrated. When its principle weight concentrated near the rim, rotating at high speed, the maximum gyroscopic inertia effect will be obtained.

W_d = mg x N = Weight of disc

Let W_d= weight of disc =mg, N (or) Kgm/s^2

D = Diameter of disc, m

M = mass of disc, = Wd/g, (N-s^2)/m or Kg

g = gravitational acceleration, 9.81 m/sec^2

For disc

$$I = 1/2 \times \frac{W_d \times (D/2)^2}{g} \quad \text{in } Nms^2 \text{(or) } Kg - m^2$$

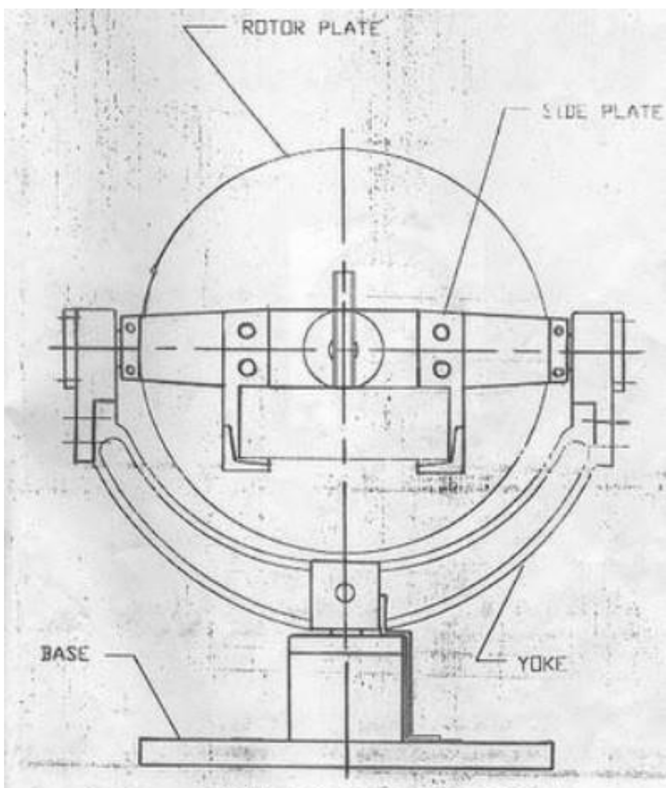
Velocity of spin $\omega = 2\pi N/60$ rad /sec

The angular velocity of rotor is called velocity of spin

Where n= speed of motor in rpm

Velocity of precession $\omega_p = d\theta/dt = \pi\theta/180\ t$, rad/s

Let dθ is the angle of precession and dt is the time taken for the corresponding precession, then the angular velocity of rotation of the rotor about an axis (OZ) perpendicular to both spin and couple axis is called velocity of precession.



FRONT VIEW OF GYROSCOPE

GYROSCOPIC COUPLE :(C = Iωωp, in Nm)

The couple generated due to change of direction of angular velocity of rotor is called gyroscopic couple. It gives rise from gyroscopic acceleration.

Applied torque = (C = Wa, N-m)

The torque applied to change the direction of angular velocity of rotor is called applied torque. Numerically it is the product of weigh (w) placed in the weight stud and its distance (a) from the center of the disc.

PROCEDURE:

1. Connect the motor of the gyroscope to an AC supply through dimmer stat.
2. Adjust the balance weight slightly if required using the bottom clamp screws.
3. Set the dimmer stat to zero position and put on the supply
4. Start the motor by speed controller and adjust the rotor speed.
5. Note down the rotor speed with the help of digital indicator when it becomes steady (it may take around 5 min to stabilize). Take care not to exert pressure on rotor shaft.
6. Place the required weight on the weight stud and at the same instant start the stop watch. Note down the time required for θ degree (say 450) precession.
7. Repeat the procedure for different weights and precessions.
8. Measure and record the distance between the center of disc and center of weight stud.
9. Tabulate the results

OBSERVATION TABLE:

Speed	**Angle in degree**	**Angle in Radian**	**Time taken**	**Wt in Kg**	**w in N**	**Linear Velocity of disc**	**Experimental linear velocity of precision**	**Theoretical linear velocity of precision**	**Torque exp**	**Torque theoretical**

Disc rotor Thickness = 10mm.

Disc rotor Diameter = 250mm

Distance between the center of disc and center of weight stud =195mm

Density =7820 Kg/m^3

Moment of inertia of disc, $I = Mr^2/2$

Formula Used:

1. Area of rotor = $\pi d^2/4$

    Where'd = disc rotor dia in m

2. Angle in radian = $\theta\pi/180$

3. Applied torque $T_{exp} = I \times \omega \times \omega_p$

    Where $I = Mr^2/2$

    $\omega = 2\pi N/60$

    $\omega_p = d\theta/dt$

4. $T_{theo} = W \times L$

SAFETY PRECAUTIONS:

1. Set the dimmer stat to zero position and put on the supply
2. Take care not to exert pressure on rotor shaft.

RESULT:

EXPERIMENT 5

UNIVERSAL GOVERNOR

AIM:

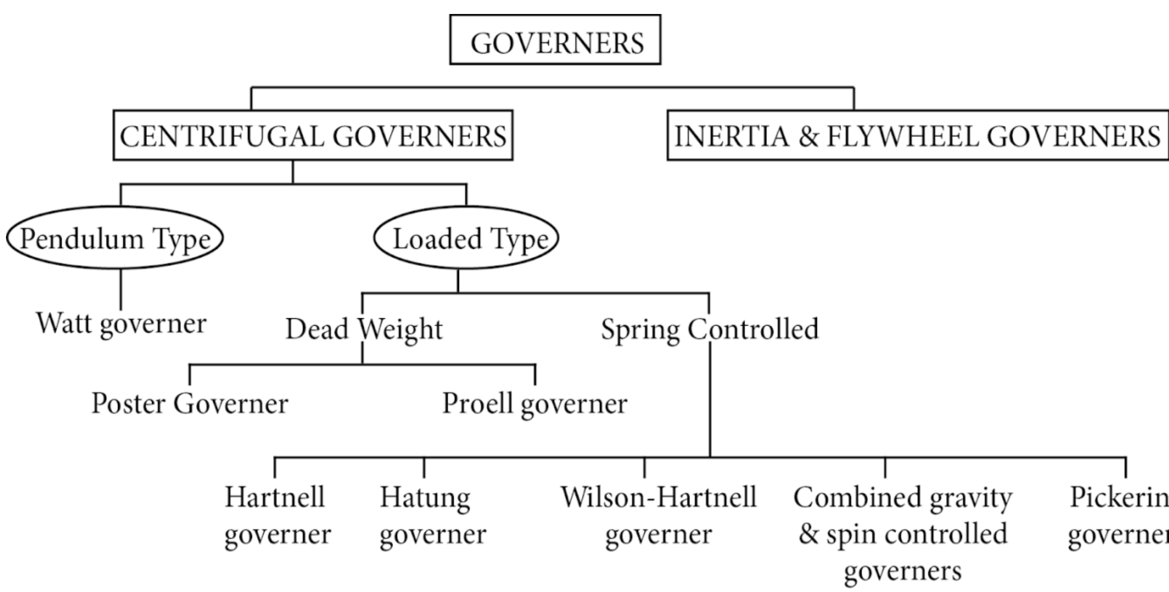
1. Determination of characteristics curve of sleeve position against controlling force and speed
2. Plotting of characteristics curves of radius of rotation.

INTRODUCTION:

One of the simplest examples of a mechanical feedback control systems is GOVERNER. A governor is a device used to control or maintain the speed within the prescribed limit for varying load conditions. As the load on the engine shaft increased, the speed of the shaft decrease and this is transmitted into the spindle by using a bevel gear. As the spindle speed decrease and hence the ball moves towards which in turn increases the fuel supply to the engine thereby the speed is brought to a constant. When the load on the engine decreases, the engine speed increases and also the spindle speed. Due to this increase in speed the centrifugal force on the governor increases, which makes the fly balls move outward and the fuel supply to the engine, is decreased thereby the speed is brought to a constant.

THEORY:

Governors are a device used to regulate the mean speed of an engine. Governors can be classified as follows.



1. **Watt governor :** Simple centrifugal governor with arms and links fitted with known masses without any center load on the sleeve.
2. **Porter governor:** This is same as watt governor with extra center load on the sleeve.
3. **Proell governor:** This is also centrifugal type of governor with masses attached at the end of an extended arm. In the Proell governor, with the use of fly Weights (Forming full ball) the governor becomes highly sensitive. Under these conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

DESCRIPTION

The drive unit consists of a small electric motor connected to the drive shaft directly by means of love joy coupling. Motor and main shaft are mounted on a rigid Base frame in vertical fashion. The spindle is supported in a ball bearing. The optional governor mechanics can be mounted on spindle. Precise speed control is afforded by the autotransformer. The speed of the governor is measured with proximity sensor and RPM indicator fitted on front panel of the box. A graduated scale is fixed to the sleeve assembly, top surface of the table as reference and guided in vertical direction. The center sleeve of the porter and proell governor incorporates a weight sleeve to which weights can be added. The Hartnell governor provides means of varying spring rate and initial compression level and mass of rotating weight. This enables the Hartnell Governor to be operated as a stable or unstable governor.

The apparatus is designed to exhibit the characteristics of the spring-loaded governor and dead weight governor. The apparatus can perform following experiments on –

1. **Watt governor.** **3) Proell governor.**
2. **Porter governor.**

Parts Details:

1. **Spindle:** Main drive shaft, which is driven by the PMDC motor of ½ HP. This is called as spindle, which is driven by the crankshaft.
2. **Sleeve:** The known mass, which slides freely on the spindle.
3. **Arms:** This is the connecting part of the sleeve. This is attached with known masses. Separate arms with balls are provided to conduct proell governor also.
4. **Links:** This is the connecting part of the arms and spindle.
5. **Ball:** This is the known mass attached to the links which rotates with spindle.

PROCEDURE:

The governor mechanism under rest is fitted with the chosen weights and spring where applicable and inserted into the drive unit. The following simple procedure may then be followed. The control unit is switched on and the speed control slowly rotated, increasing the governor speed until the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale. The sleeve position and speed are then recorded. Speed may be determined using a hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve moments and readings repeated at each stage throughout the range of sleeve movement possible.

The result may be plotted as curves of speed against sleeve position. Further tests are carried out changing the value of one variable at a time to produce a family of curves.

OPERATING INSTRUCTIONS:

For obtaining the graphs as mentioned above following instructions may be followed.

1. Arrange the setup as a porter / proell governor as shown in figure. This can be achieved by removing the upper sleeve on the vertical spindle of the governor and using proper linkages provided.
2. Make proper connections of the motor.
3. Increase the motor speed slowly and gradually.
4. Note the speed by tachometer and sleeve displacement on the scale provided.
5. Plot the graph of speed V/s sleeve displacement for watt porter Proell governor.
6. Plot the graph of speed V/s governor height for watt governor.
7. Plot the governor characteristics after doing the necessary calculations.

PRECAUTIONS:

1. Do not keep the main 'ON' when trial is complete.
2. Make proper connections of field of armature of the D.C Motor.
3. Increase the speed gradually.
4. Take the sleeve displacement reading when the pointer remains steady.
5. See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
6. The gear box may be oiled after every six months period.
7. While closing the test bring the dimmer to zero position and then switch 'OFF' the motor.

PORTER GOVERNOR:

Dimensions:

1. Length of each line l = 125mm
2. Initial height of governor 'h_o' = 105mm
3. Initial radius of rotation 'r_o' = 116mm
4. Weight of each ball assembly 'm' = 0.5kg
    a. Take the actual weight of sleeve weights
    b. Go on increasing the speed gradually and take the readings of spedd of rotation 'N' and corresponding sleeve displacement 'x'.

Radius of rotation 'r' at any position could be found as follows:

1. Find out height 'h' = $h_o - x/2$
2. Find by α using cos α = h/l
3. Then radius of rotation r = 50 + l sin α

S.NO	Speed in RPM	SLEEVE DISPLACEMENT 'x'	HEIGHT cos α = h/l	RADIUS OF ROTATION	FORCE

Force F = $m\omega^2 r$

Where m = weight of ball assembly

$\omega = 2\pi N/60$

r = radius of rotation

Following graphs may then be plotted to study governor characteristics

1. Force vs radius of rotation
2. Speed vs sleeve displacement'

PROELL GOVERNOR:

In the proell governor, with the use of fly weights (Forming full ball) the governor becomes highly sensitive. Under these conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using ball flyweight on each side.

DIMENSIONS:

1. Weight of each ball assembly 'm' = 0.5Kg
2. Weight of sleeve = 2 Kg. Each
3. Extension of length BG =75 mm

Go on increasing the speed gradually and take the readings of speed of rotation 'N' and corresponding sleeve displacement 'x'. Complete the following table.

Sl. No	Speed in RPM "N"	Sleeve displacement "x"	Radius of rotation "r"	Force "F"

Draw the following graph:

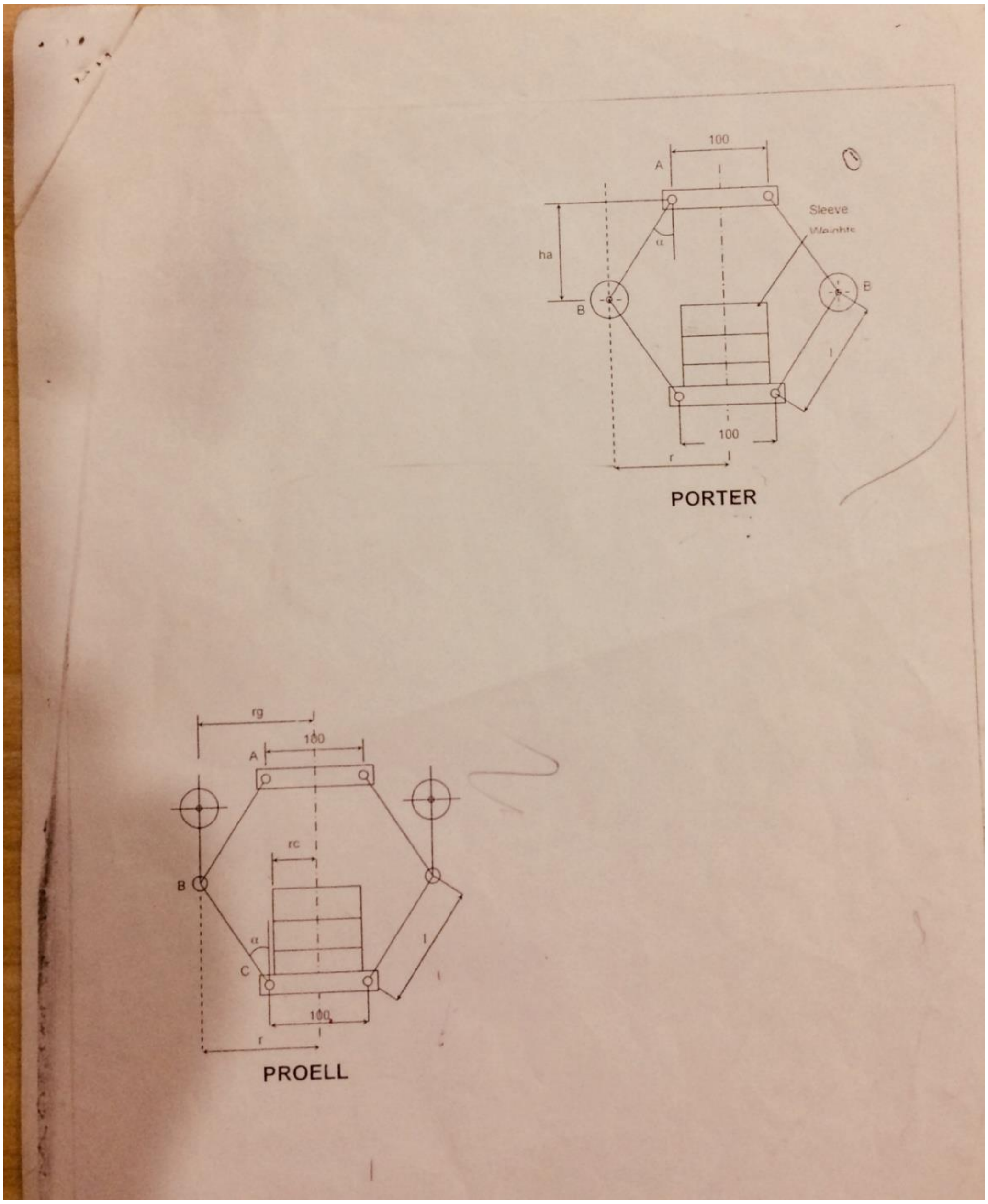
a) Keeping static position draw the graph of sleeve displacement vs radius of rotation of balls by actual measurement.
b) Plot the graph of speed vs sleeve displacement when the governor is rotating.
c) Then for any displacement of the sleeve it is possible to find r and N

d) Force $F = m\omega^2 r$

Where m = weight of ball assembly

$\omega = 2\pi N/60$

r = radius of rotation



RESULT:

The characteristics of a governor were studied and the controlling force and frictional force were determined for various speeds and weights on sleeve.

EXPERIMENT 6

WHIRLING OF SHAFT

AIM:

To determine the whirling speed for various shaft sizes experimentally and compare the same with theoretical values.

APPARATUS:

Shafts, digital tachometer, AC voltage regulator, chuck key.

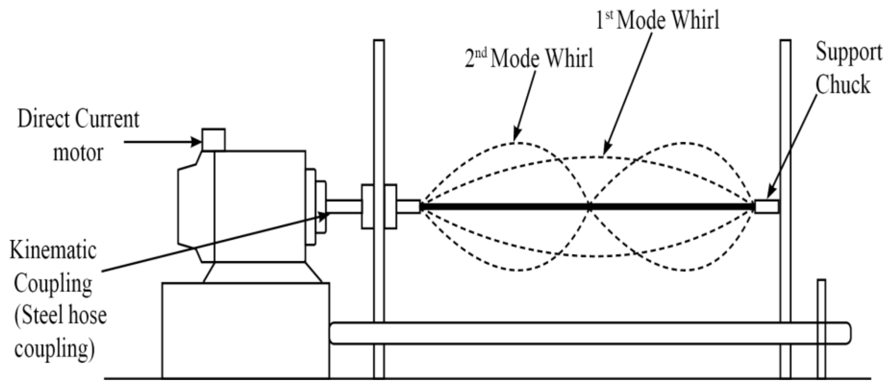
THEORY:

The speed at which the rotating shaft vibrates violently in the transverse direction is called critical whirling speed. Critical speed of a shaft because due to self weight of the shaft and also if a body or disc mounted upon the shaft rotating about it. When a rotor is used the center of gravity of the disc must lie on the shaft axis.

Critical speed of shaft depends on the following factors:

1. Length of the shaft
2. Diameter of shaft
3. Bearing support i.e., fixed or free
4. Self weight of the shaft or the location of load carried by shaft when an extra disc is attached

EXPERIMENTAL SETUP:



PROCEDURE:

1. Measure the dimensions of the shaft or specimen using calipers
2. Mount the shaft on to the machine by inserting it through the central hole of the retainer.
3. Switch on the speed control unit and the 1st natural frequency is read (1st mode of vibration). When the speed is increase further the shaft begins to vibrate violently as it nears the critical speed.
4. Once the critical speed is passed, the shaft reestablishes and on further increase of the speed, the second natural frequency is reached.
5. Measure the speeds of rotation of the shaft at its first & second natural frequencies directly with the tachometer.
6. Measure speed three times and use the average value for calculation.

FORMULAE:

1. Weight of shaft: W = Density x Volume

$$\boxed{W = \rho \times \frac{\pi d^2}{4} \times L} \quad (N)$$

Where d = Diameter of shaft (m)

L = Length of shaft (m)

$$\boxed{I = \frac{\pi}{64} d^4} \quad (m^4)$$

3. Static deflection due to self weight of shaft:

$$\boxed{\delta_S = \frac{5WL^4}{385EI}}$$

Where E = Young's Modulus (N/m^2)

4. Natural frequency of transverse vibration:

$$f_n = C \times \sqrt{(E.I.g)/(w.\ L^4)}$$

Where C is a constant value that depends on the end conditions of shaft.

Case	End Condition	Value of C	
		1st Mode	2nd Mode
1	Fixed – supported	1.572	6.3
2	Fixed – Fixed	3.75	8.82

5. Critical speed:

$$Nc_{thy} = f_n \quad \text{rps}$$

$$\boxed{Nc_{thy} = f_n \times 60 \quad (\text{rpm})}$$

OBSERVATION:

1. Young's Modulus for steel E = 2.06 x 10^{11} N/m^2

2. Density of mild steel ρ = 7800 Kg/m^2

3. Length of shaft L = 0.9m

4. Acceleration due to gravity, g = 9.81 m/s^2

TABULAR COLUMN:

Diameter of shaft (m) d	Mass moment of Inertia of shaft I (m^4)	Weight of shaft per meter W (N/m)	Natural Frequencies	Whirling speed (rpm)	
				Nc_{exp}	Nc_{theory}
			1st Mode		
			2nd Mode		

RESULT:

The critical speed of the given shaft is obtained and tabulated.

EXPERIMENT 7

CAM ANALYSIS APPARATUS

AIM:

To study the profile of given cam using cam analysis system and to draw the displacement diagram for the follower and the cam profile. Also to study the jump-speed characteristics of the cam & follower mechanism.

INTRODUCTION:

The Cam Analysis Machine (CAM) has been designed to enable students to observe the dynamic behavior of cam followers under various operating conditions. Cam are mounted on the end of a shaft driven by a variable speed motor.

A cam is a machine element such as a cylinder or any other solid with a surface of contact so designed as to give a predetermined motion to another element called the follower.A cam is a rotating body importing oscillating motor to the follower. All cam mechanisms are composed of at least there links viz: 1.Cam, 2. Follower and 3. Frame which guides follower and cam.

DESCRIPTION:

The CAM consists of a set of cams, a set of springs and other components. A D.C. shunt wound geared motor is directly coupled by a flexible coupling to an extension shaft, on which is mounted a flywheel to reduce the fluctuation in speed caused by the variable torque required to lift the follower. The cam is mounted on a taper on the end of the shaft, and secured on the shaft by a nut. The followers are of the flat face or roller type, and are mounted on the end of a vertical bar. A drilling in top end of the bar accommodates a steel ball, which is retained in position by a second bar carrying a spring and optional masses. The presence of the steel ball ensures that only an axial force is transmitted to the upper bar. The top end of the spring is supported by a crossbar mounted on two vertical pillars on the base plate. A pen traces a record of the follower amplitude on paper. The paper is fastened to a cylindrical drum driven by a timing belt from the camshaft. The camshaft speed may be measured by means of a Stroboscope.

Types of cams:

- Circular arc cam
- Eccentric cam
- Tangent cam

Types of follower:

- Mushroom follower
- Roller follower
- Knife edge follower
-

PROCEDURE:

Cam analysis system consists of cam roller follower, pull rod and guide of pull rod.

1. Set the cam at 0° and note down the projected length of the pull rod
2. Rotate the can through 10° and note down the projected length of the pull rod above the guide
3. Calculate the lift by subtracting each reading with the initial reading.

JUMP-SPEED:

1. The cam is run at gradually increasing speeds, and the speed at which the follower jumps off is observed.
2. This jump-speed is observed for different loads on the follower.

OBSERVATION:

Diameter of base circle =mm,

Lift = mm,

Diameter of cam shaft = mm

Diameter of follower shaft = mm,

Diameter of roller = mm,

Dwell period =

Type of follower motion = SHM (during ascent & descent)

1. Cam profile

Sl. No.	Angle of rotation (degrees)	Lift in mm	Lift + base circle radius (mm)

2. Jump-speed

Sl. No.	Load on the Follower, F (N)	Jump-speed N (RPM)

GRAPH:

Load on the follower vs. jumping speed

RESULT:

EXPERIMENT 8

FREE VIBRATIONS

AIM:

To study the undamped free vibration of equivalent spring mass system.

DESCRIPTION:

It is designed to study free forced damped and undamped vibrations. It consists of M.S. rectangular beam supported at one end by a turning in ball bearing. The bearing housing is fixed to the side member of the frame. The other end of the beam is supported by the lower end of helical spring. Upper end of spring is attached to the screw.

The exciter unit can be mounted at ant position along the beam additional known weights may be added to the weight platform underside the exciter.

PROCEDURE:

1. Support one end of the beam in the slot of trunnion and clamp it by means of screw.
2. Attach the other end of beam to the lower end of spring.
3. Adjust the screw to which the spring is attached such that beam is horizontal in the position.
4. Weight the exciter assembly long with discs and bearing and weight platform.
5. Clamp the assembly at any convenient position.
6. Measure the distance L1 of the assembly from pivot. Allow system to vibrate freely.
7. Measure the time for 10 oscillations and find the periodic time and natural frequency of vibrations.
8. Repeat the experimental by varying L1 and by also putting different weights on the platform.

OBSERVATION TABLE:

S.no	w	L1	No. of osc n	Time for n oscillations in sec T	Periodic time T_{expt} t/n	T_{theo}

CALCULATIONS:

M= (W+w)/g

Me = M (L1/L)

$T_{theo} = 2\pi \sqrt{\frac{Me}{k}}$

Where W = weight of exciter assembly along with weight platform = 15kg

w = weight attached to exciter assembly

L1 = distance of weight from pivot

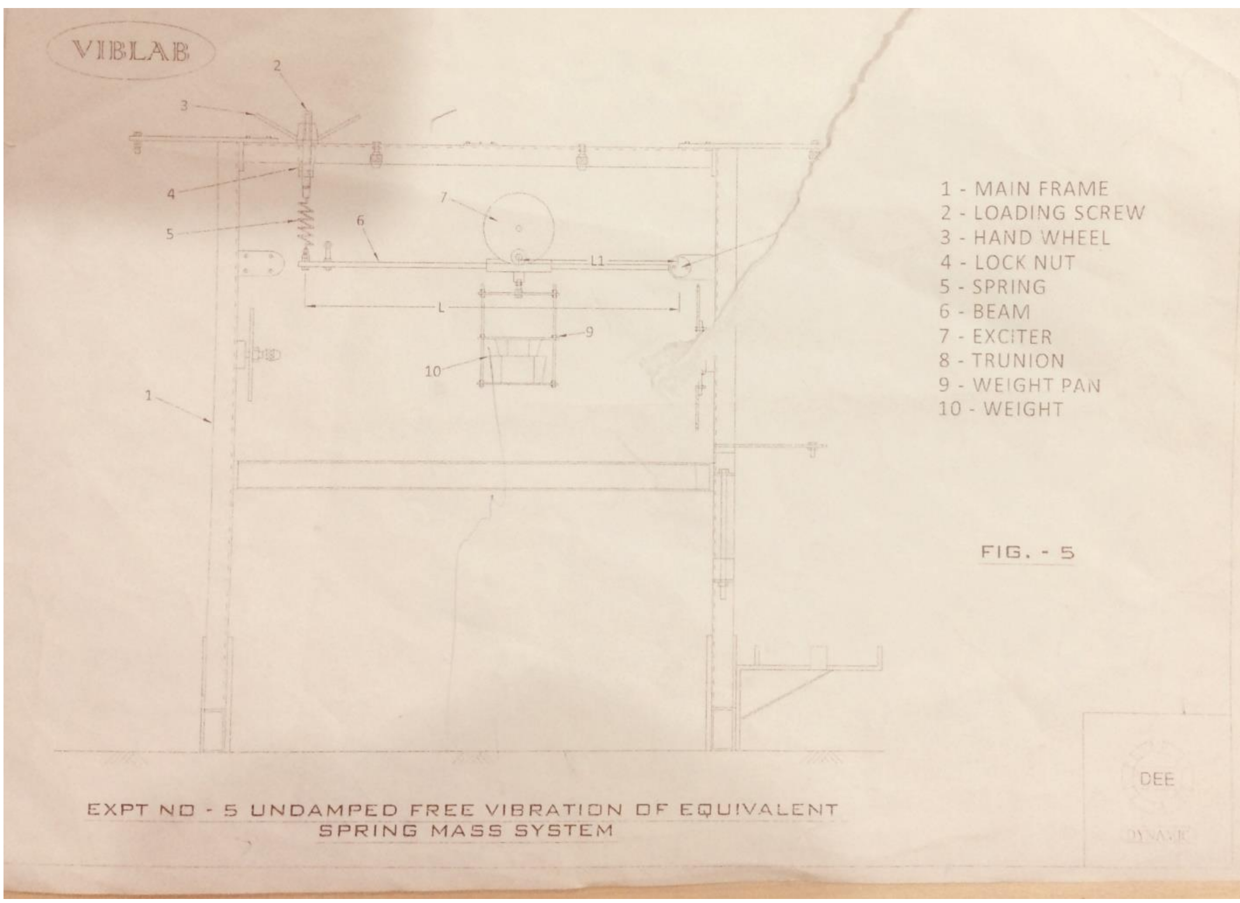
L = distance of spring from pivot

M = mass

Me = equivalent mass at the spring

g = gravitational acceleration

K = Stiffness of the Spring = 0.4 kg/cm



RESULT:

EXPERIMENT 9

FORCED VIBRATIONS

AIM:

To study the forced vibration of equivalent spring mass system.

DESCRIPTION:

It is similar to that described for free vibrations experiment. The exciter unit is coupled to D.C variable speed motor through the flexible shaft. Speed of the motor can be varied with the dimmerstat provide on the control panel. Speed of rotation can be known from the speed indicator on control panel. It is necessary to connect the damper unit to the exciter.

Amplitude record of vibration is to be obtained on the strip chat recorder is 33mm/sec.

PROCEDURE:

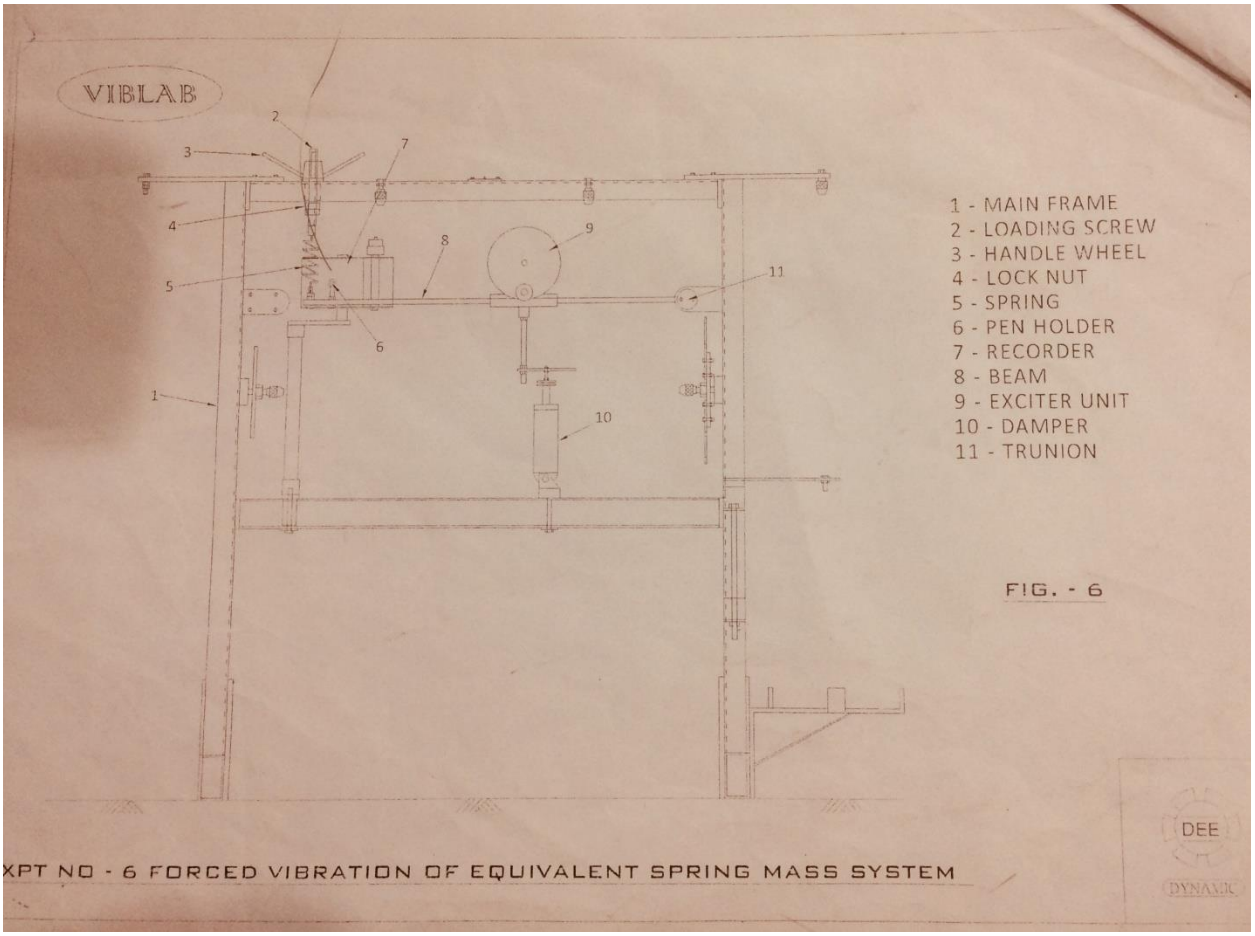
3. Arrange the setup as described for expt no. 8
4. Connect the exciter to D.C. motor through flexible shaft.
5. Start the motor and allow the system to vibrate.
6. Weight for 3 to 5 minutes for the amplitude to built the particular forcing frequency.
7. Adjust the position of strip chart recorder.
   Take record of amplitude vs time on strip chart by starting recording motor. Press the recorder platform on the pen gently. Pen should be wet with ink. Avoid excessive pressure to get good record.
8. Take record by changing forcing frequencies.
9. Repeat the experiment for different damping.
   Damping can be changed by adjusting the holes on the piston of the exciter.
10. Plot the graph of amplitude vs frequency for each damping conditions.

OBSERVATION:

Speed in RPM	Forcing Frequency in Cps = Speed/60	Amplitude mm

CALCULATION:

Plot the graph of amplitude vs frequency for each settings



RESULT:

EXPERIMENT 10

JOURNAL BEARING

AIM:

Determine the pressure distribution of lubricating oil at various load and speed of a Journal bearing.

THEORY:

Rotating shafts are widely used in engineering practice, which are supported by different types of bearing viz. ball bearing, roller bearing, bush bearing, etc. Bush bearing is one of simple and cheap of bearing and it was quite common in earlier days. Now a day also bush bearing finds application in many places like crank shafts, connecting rod lathe spindles etc. the portion of shaft resting over the bearing is called journal. The bearings are lubricated by supply of oil which may be pressurized or gravity fed. Clearance is provided between journal and bearing diameter to permit the flow of oil. This oil maintains low coefficient of friction and also carries heat generated in bearing. Hence it is essential to keep required oil flow to the bearings. Because of clearance provided, shaft and bearing centers became offset. When shaft rotates, oil is drawn in due to viscosity and a typical wedge shaped film gets established between journal & bearing. Du to wedge action oil pressure is developed which breaks the surface to surface contact and takes the load which minimizes the surface wear and reduces coefficient of friction, reducing power loss in friction. The main object is to determine the coefficient of friction and required oil flow to maintain the coefficient of friction and to cope up side leakage.

APPARATUS:

The apparatus consists of a journal with brass bush pressed over outer diameter, which rotates in steel bearing. Bearing caps are provided on both sides of bearing to which loading attachment is fixed. The journal is rotated by a variable speed D.C. motor. A torque arm with scale is fixed to bearing, which is used along with sliding weight. An oil collector tray is provided for measurement of oil flow from bearing.

PROCEDURE:

1. Fill up sufficient oil in the oil supply tank and open the bottom cock so that oil is let to the bearing.
2. Adjust the pressure gauge at 0^0. Adjust the pointer on torque arm to match with the zero on the scale fitted on the frame.
3. Put ON the supply and start the motor at required speed.
4. Pressure will start to develop put the required weight in the weight hanger.
5. Put small weight in balancing hook & adjust the distance so that the pointer should again coincide with zero on the scale. Note down weight & its distance.
6. Wait for some time for pressure to build up. When pressure remains steady, note down pressure. Similarly note the pressures on either side of 0^0 at the intervals of 5^0 or 10^0.
7. Repeat the procedure for different speeds and loads and complete the observation table.
8. Plot the graph between angle vs. pressure distribution.

OBSERVATION TABLE:

S.NO	SPEED N	LOAD W	TORQUE ARM	
			WEIGHT W	Distance (m)

PRECAUTIONS:

1. Always put clean SAE 40 oil in the tank.
2. Collect the oil collected in collecting tank & pour it in the oil tank every five minutes.
3. While applying the weights, keep them gently.
4. Operate all switches & controls gently.

RESULT:

EXPERIMENT 11

STATIC & DYNAMIC BALANCING

AIM:

To find static the position and magnitude of balancing masses in a given system of rotating masses.

APPARATUS:

It consists of a frame, which is hung by chains from the main frame. A shaft rotates within bearings in the frame. Four eccentric weights are supplied which can be easily fitted over the shaft.

INTRODUCTION:

It is basic equipment used for analyzing the concept of statically and dynamically balancing of rotating masses.

BASIC SETUP:

The equipment consists of a rigid frame of T shape. We may call this as Supporting frame; three nuts are provided on it holds the equipment on Horizontal level by tightening screws. A main frame consists of Four steel flat is also provided with equipment, this equipment consists Horizontal shaft Mounted between two bearings. This shaft having a pulley Allows with a hock and pointed on the shaft. Graduated scales 360^{o} four Rotating weights with making of number letters are provided. The shaft Driven by a 230 Volts Single phase electric motor, mounted under the main Frame through a belt, and this motor run by closed dimmer also provided separately.

PROCEDURE FOR STATIC BALANCING:

Clamp the main frame on the supporting frame by a nut and bolt. Remove the drive belt clamp the weight having mark on the main shaft by alter key provided with the machine. Ensure that weight is firmly clamped. It should move along with the shaft only while doing this, care should be taken on have the pointer at 00. Now attach two weight pan by alight flexible string to the hook provided on pulley. Let this string (thread) pass through the groove provided on pulley. Now add steel balls in any one of the weight pan ensure that the weight pan are in Horizontal level. Go adding weights until the rotating weights falls freely. At this time pointer should be 90^0. Count down the steel balls prospectively note down steel balls for all weights.

To conduct experiment on static balancing:

1. Record this table.

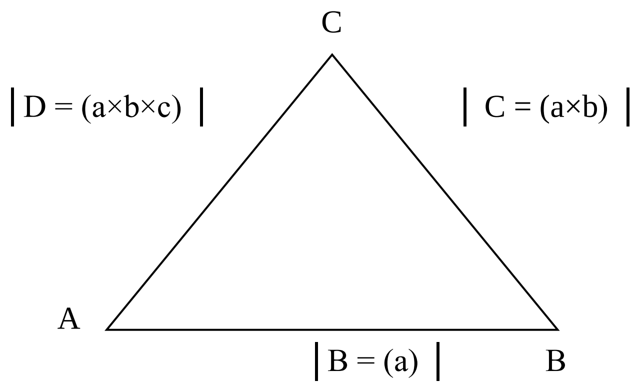
Weight No.	No of steel balls	weight in grams (q)x no of steel balls
A		
B		
C		
D		

q = weight of each steel balls.

2. Steel the four rotating weights at random. Select the any random distance between them.
3. Find the couple for all the weights with respect any one of the force (weight).the general idea of this couple binding will be number.

Weight No.	Distance	(weight x distance)	Couple
A	0	A x 0 =	
B	(a)	B x (a) =	
C	(a+b)	C x (a+b) =	
D	(a+b+c)	D x(a+b+c) =	

4. Now drawn couple polygon.

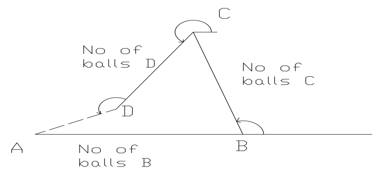


5. Here we will get the angle of weight

θ_1	
θ_2	
θ_3	

6. Now we find angle θ_4 for four polygons. By taken suitable scale for (no of balls) drawn the four polygons.

θ_1	
θ_2	
θ_3	



7. Now we get all the angles, note down here.

θ_1	
θ_2	
θ_3	
θ_4	

DYNAMIC BALANCING PROCEDURE:

1. Attach these weights as per these angles on the shaft with distance. Scale is provided on main frame for frightening weights as shaft at required angle use of knob may be done.
2. Remove the main frame from supporting frame. Attach hook and chain to the frame at the given taping, lift the main frame and attach it to the supporting frame by chain and steel tighten the nut. Now the main frame is hanging. Adjust the level by chain and nut arrangement.
3. Put these drive on the motor pulley and pulley provided on shaft. Now start the motor and observe the performer and speed Tachometer has been provided with equipment.
4. We can say the rotating masses as perfectly dynamically balanced when these exists zero vibration to the frame.

For Experiment No.1

No of weight.	No of steel balls	Weights on each
A	76	532
B	70	490
C	65	455
D	60	420

Weight of each balls, q = 7 grams.

2. Random distance:

3. We find couple:

Weight.	Distance (cm)	Couple
A(532)	0	
B(440)	3	1470/100 = 14.7
C(450)	5	2275/100=22.75
D(420)	8	3360/100=33.60

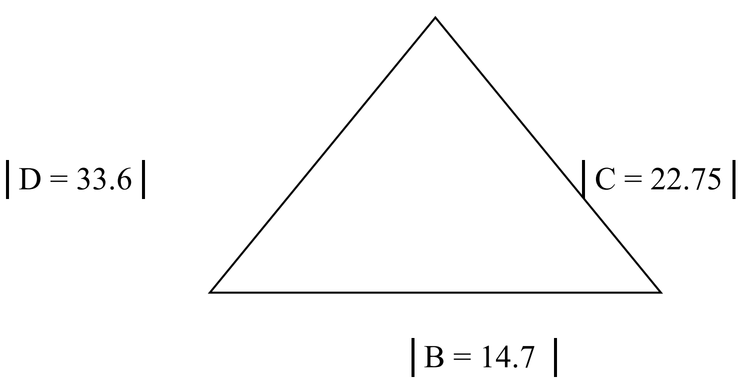
4. Now we draw the couple polygon:

Now we got angle

$\theta_{1} = 0$

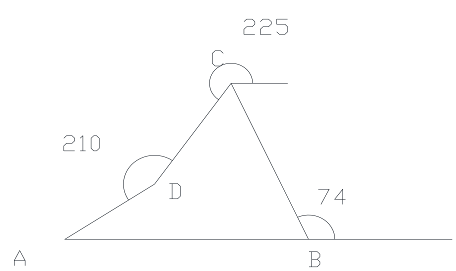
$\theta_{2} = 74^{0}$

$\theta_{3} = 225^{0}$



5. Now we find angle θ_4 for force polygon:

A	76
B	70
C	65
D	60



Diagram

RESULT: